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*Surveys of Communist World Scientific and Technical Literature*

CYBERNETICS AND PSYCHOLOGY

Summary of Data

(Report No. 1 in this series)

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## FOREWORD

This report, prepared in response to ATD Work Assignment No. 78, Task 21, is a collection of abstracts on the biological and psychological applications of cybernetics. Soviet popular-scientific periodicals published during the period 1959-1964 were reviewed for the materials which make up the report. All sources cited are available at either the Aerospace Technology Division of the Library of Congress or in the collections of the Library itself. Further reports on this subject will be issued as more data become available. Full translations of some of the source materials used in this report may be available from other agencies or commercially. Interested readers may obtain translation data for individual sources by indicating source numbers from the bibliography list on the form attached at the end of this report and returning it to the Aerospace Technology Division.

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## CYBERNETICS AND PSYCHOLOGY

### I. BIOCYBERNETICS

1. Glushkov, V. M. [Academician, Vice President, Academy of Sciences Ukrainian SSR] Making cybernetics a real helper to human mental activity. Tekhnika molodezki, no. 6, 1962, 28-30.

After stating that most of the arguments used to demonstrate the impossibility of "thinking" by computers could be used equally well to disprove the possibility of human thought, the author defines informational modeling as that in which all essential elements of the modeled object are correlated with an information code. If the coding system is known, the behavior of the modeled object can be inferred from the behavior of the model. There is also a deeper level of modeling in which the modeling process embraces not only external behavior but also the internal structure of the modeled object.

Though informational modeling is said to be presently capable of modeling any given phase of human mental activity, so far only systems consisting of hundreds of neurons, rather than the billions making up a human brain, have actually been modeled. Such direct, structural modeling of the human brain is quite unnecessary, however. In many cases, "external" modeling of the brain's behavior suffices. At present, this behavioral approach to modeling is the one most widely used.

One of the main obstacles to progress is insufficient knowledge concerning human thought processes, a subject which is often glossed over with references to "intuition," the "unconscious," etc. Detailed study has turned up evidence of set patterns in intuition, indicating the existence of complex but nonetheless fully comprehensible systems of rules governing this process. Further study should be given to these problems.

Unless progress in the automation of some types of human mental activity (e.g., national forecasting and planning) can match the current pace of industrial automation, it is estimated that by 1980 the entire adult population of the USSR will be obliged to work full-time to keep up with the problems of economic and industrial planning. Preliminary steps have already been made: the "Kiev" computer at the Computing Center of the Academy of Sciences Ukrainian SSR was

used in 1961 to optimize the transport of sugar beets from farm to refinery, at a saving of 8.6% below the cost of the Gosplan experts' scheme. Another example is the standard program for optimal railroad profiling produced at the Computing Center of the Academy of Sciences Ukrainian SSR with the collaboration of workers from the Institute of Transportation Construction in Moscow.

2. Glushkov, V. M. [Academician, Vice President, Academy of Sciences Ukrainian SSR] Modeling of thought processes. Priroda, no. 2, 1963, 3-13.

Modeling of a thought is one of the most fascinating and, at the same time, complicated problems of cybernetics. The wide attention given recently to this problem is attributed to two factors. First, the transition from pure observation of a working human brain to actual brain modeling will help to reveal at least some of the mysteries which still surround the process of thinking. Second, modeling of thought processes with the use of the latest techniques in cybernetics opens up new avenues to the mechanization of the mental activity of man.

The present level of science and technology does not yet make it possible to build a human brain model. There is still a long way to go in the study of the brain structure and the development of new techniques in the design and assembly of electronic elements before a serious attempt can be made to design the most perfect of the live organs. Until then, a more modest goal should be pursued, e. g., that of modeling neural networks consisting of several hundreds of neurons. Using such models, the biologist could check the various hypotheses involving the transmission of information from one neuron to another and study in greater detail the genesis and extinction of conditioned reflexes.

It is now possible to produce artificial cells that could be used in a computer system in place of relays, and work has been initiated on the question of the practicability of actually launching such an undertaking. The relatively high cost of electronic equipment and the need for trained personnel to operate such a computer are among the factors to be considered. The Institute of Cybernetics of the Academy of Sciences Ukrainian SSR has recently built a model of a single neuron.

Faced with the impossible task of modeling a human brain, it is necessary to look in another direction, perhaps to the designing of an automaton. As has been said, each type of mental activity would involve a quantity of neurons beyond

the capacity of any electronic computer or other digital device. To answer the question of whether it is absolutely necessary to follow blindly the pattern of a human brain, one need only look at the history of technology to see that a blind imitation of nature has often slowed down technological progress.

The algorithm-based automation of mental phenomena is presently very important in cybernetics. Generally speaking, the algorithmic description of a "thinking process" makes it possible to model and automate this process with currently available electron computers. A computer does what it is programed to do, and it can be programed to perform inductive operations and to learn.

The Institute of Cybernetics of the Academy of Sciences Ukrainian SSR has designed a special unit called a universal reading automaton. The purpose of this device, which is attached to a general-purpose electronic digital computer, is to feed into the computer arbitrary images made up not only of black and white areas but of various halftones as well. With this device, the computer can model and make rapid verification of various visual recognition systems including self-improvement and self-learning systems. A number of such systems have been tested recently. Some of them, e.g., the system involving the learning of discrimination among geometrical figures, simulate quite well the adaptive functions of the human brain. In other words, a computer suitably programed is capable of showing intelligent behavior.

The algorithmic scheme of image recognition proposed by the American scientist F. Rosenblatt is worth mentioning. Called the "perceptron," the scheme is a probabilistic model for information storage and organization in the brain.

A theoretical study by Glushkov of the perceptron's operation revealed that its organization of the learning process does not always yield positive results. A number of important features inherent in man's learning (relative to the problem of image recognition) are reflected poorly or not at all. Methods more efficient than the perceptron for modeling thought processes are said to be already in use by the Institute of Cybernetics.

If machines are to be of cybernetic interest, they must be able to perform operations of a deductive and inductive nature. Recent experiments at the Institute of Cybernetics involved self-organization and self-perfection in the modeling of logical thinking and language learning. Of special interest are the semantic constructions which set up rules for

the automatic recognition of meaning. Another series of experiments dealt with the modeling of biological evolution. A rather simple "world" was built in which the "law of nature" controlled the transfer of "food" from one section of the world to another. The "living creatures" of this world were modeled as programmed automata. The natural selection process and the adaptability of automata to the law of nature selected were simulated.

The first steps toward constructing a general theory of self-organizing systems to be used for modeling thought processes have thus been made. Through a combination of the techniques outlined above and the addition of new techniques, it is hoped that solutions will be found to the mysteries of human thought and that a solid foundation will be established for the automation of thought processes.

4. Parin, V. V. [Professor] The mathematics of life—ideas of cybernetics in biology and medicine. Priroda, no. 7, 1962, 22-27.

The author describes, in popular terms, the principles of cybernetics and its applications in medicine and biology. He shows how a better understanding of the functioning of living organisms can be fed back to the development of cybernetic equipment. Work on the mechanism of self-regulation of a living cell in the process of its adaptation to sudden changes of environment has been conducted under the supervision of G. M. Frank. A study of biological systems in motion has been carried out by N. A. Bernshteyn, Corresponding Member of the Academy of Medical Sciences, USSR. Bernshteyn advanced the hypothesis that the brain contains a coded model of every dynamic act; the model is capable of being modified and corrected in the course of its realization. A model of the interrelation of excitation and inhibition designed by G. V. Savinov, L. V. Krushinskiy, and others makes it possible to investigate the protective mechanism operating in the nervous system during the action of strong irritants.

The problem of the identification of images has been studied in bionics. Reference is made to an investigation of the organs of vision of the horseshoe crab (*Limulus polyphemus*) carried out by the General Electric Laboratories in the United States. Significant contributions to this development have also been made by V. D. Glazer and I. I. Isukkerman (both of the Institute of Physiology of the Academy of Sciences, USSR). Results in the determination of color information coding in the retina have been obtained by N. D.

Nynberg. The processing of light signals in the retina has been studied by A. L. Byzov. Other efforts have been directed toward the identification of both definite and arbitrary images. Attention is called to E. M. Braverman's machine which is capable of "learning" to recognize visual images. M. M. Bongard is reported to have modeled the process of image recognition by an electronic computer. The general theory of image identification is treated by L. P. Krayzner.

The multiple-circuit system of self-regulation is discussed. This involves regulation by several mechanisms which in turn may be objects of regulation. The interaction between several regulators is carried out by humoral and nervous mechanisms. Interaction with the environment goes through various receptors and analyzers. V. M. Khayutin is credited with establishing a connection between the constricting impulses and the degree of contraction of smooth muscles on the basis of static characteristics of kidney vessels and the posterior extremities in cats. The interdependence of biological systems is reflected in the hypothesis of S. N. Braynes and V. B. Suchinskiy concerning the general system of governing the physiological processes in a living organism. Three levels are distinguished in this system, the higher levels governing the lower. The lowest level insures homeostasis (the constancy of the basic parameters of an organism). The second level governs the adaptation of the organism, i.e., controls the coordination between the lower levels. The third level governs the lower ones on the basis of analyses of the information taken in from the outside environment via the receptors. The emergence of outside influences which necessitate a rearrangement of internal organs leads to a change of program. The functioning of the receptors (including their measuring, classifying, and analyzing functions), therefore, is a major area of investigation of immediate practical value. The problem is complicated by the widely changing degree of sensitivity of these organs.

In the field of automatic devices, several recent achievements are mentioned. Development is being carried on in three areas: 1) devices based on utilization of the information derived from living organisms (biological control); 2) devices for the introduction of controlling information into the organism (biological stimulation); and 3) devices replacing individual organs or functional systems which have an autonomous governing system isomorphic to that of the organism (functional prosthetics). All of these devices are essentially systems of automatic control comprising a governing unit, the object of control, and a feedback circuit with a measuring element. One of the devices mentioned is an electronic bridge device to control the functioning of



ventricles by the amplified auricular potentials (Ye. Kann and B. Babitskiy), which operates on the principle of self-stimulation. An apparatus (not yet perfected) for the circulation of blood and an artificial kidney are also mentioned.

The application of radioelectronics and cybernetics to medicine and biology has resulted in an enormous swell of data to be processed and interpreted by surgeons and physiologists. This processing is one of the immediate practical tasks for cybernetics. The application of cybernetics to diagnostics, on the other hand, is still in the research stage. The main practical developments in this area pertain to various types of recording apparatus for physicians.

It is concluded that the application of cybernetics to medicine and biology has not resulted in simplification of the classical concepts, but rather in their complication. A revolution in thinking concerning biological problems is therefore necessary to cope with the new approach. The most extensive problem will be the mathematization and "algorithmization" of all basic biological constants and postulates, and the development of appropriate methods of collecting, processing, and analyzing information. Close cooperation between representatives of the various disciplines involved will be a necessary condition for rapid progress.

4. Berg, A. [Academician. Chairman, Scientific Council on Cybernetics of the Academy of Sciences USSR] Cybernetics in the service of Communism. I. Tekhnika molodezhi, no. 3, 1962, 24-26.

Some applications of cybernetics and electronics in medicine are mentioned: 1) collection of information on the condition of organs to facilitate diagnosis; 2) direct action on the organs to effect healing; 3) assisting surgeons by temporary replacement of certain organs such as the lungs, kidneys, and heart; and 4) stimulation of heart activity by electric pulses.

5. Berg, A. I. [Academician] A science with great opportunities. Priroda, no. 7, 1962, 16-21.

Cybernetics, as a science of governing, is conceived as a modern solution for better work organization and higher productivity. Its application is most effective in the control or "optimization" of complex systems with many interacting functional elements or in cases where problems must be solved within a very short period of time. The development of cybernetics depends on analogies with the functioning of living organisms, especially with that of the human nervous

system, which, in its turn can be better studied and understood by means of cybernetics. [The author maintains that the enormously complex mechanism of a socialist, centralized economy cannot be effectively governed without reliance on cybernetic equipment]. Self-optimizing cybernetic systems are in the process of being introduced into complex production processes. Academician L. S. Pontryagin and colleagues are taking the general approach to the problem, while Professor A. A. Fel'dbaum, in association with the Institute of Automation and Telemechanics of the State Committee for Automation and Machine Building, is dealing with practical problems of application.

The maintenance of health is one of the areas in which cybernetics is being widely applied. Cybernetic apparatus is already in use, particularly in diagnostics (see Literaturnaya gazeta, 29 Mar 1962). The work of B. L. Astaurov on influencing sex and heredity by various electronic means is mentioned. The modeling of certain processes or elements of living organisms is considered to be another important field. Maintenance of the functioning of certain organs during surgical operations is mentioned as an example. Cybernetics, it is said, will create a revolution in the development of biology and medicine. In biochemistry, for instance, very important achievements were reported at the International Congress on Biochemistry in Moscow in 1961 concerning the structure of protein albumen molecules, the mechanism of conveying information on heredity (Priroda, no. 6, 1962, 102-105; no. 7, 31-36), and the functioning of a live cell.

The concluding section deals with "thinking" machines. These include electronic computers which adapt their programs as required and "optimizing" computers (Priroda, no. 4, 1962, 27-34). The author, however, denies the possibility of creating a truly "thinking" machine. In his words, "a society of thinking machines, if realized, would have no need to create man." The role of machines will be confined to the carrying out of certain mathematical and logical operations with a speed unattainable by the human brain. Without such machines the author feels that scientific and technological progress and perhaps even the realization of communism according to schedule would be impossible.

6. Berg, A. I. [Academician] Cybernetics and the social sciences. Nauka i zhizn' no. 2, 1963, 12-16.

The author advocates wider utilization of cybernetics in economic planning and management, education, law and linguistics. An adjusted (equal-level) price system for the

national product of some 70 branches of production has been calculated at the Institute of Electronic Control Machines under the direction of I. S. Bruk, Academy of Sciences USSR. Although such prices can be used for a number of economic measurements, they have not yet been put to practical use. A mathematical and economic "model of the national economy" is suggested which would form a scientific basis for price determination and for solving a number of other economic problems.

In education, the main fault of the conventional method of conveying knowledge is said to consist in the necessity of averaging: the teacher, by adapting his method and pace to the average student, neglects the needs of the rest of the class. The main problem is to make it possible to individualize the teaching process. The author introduces the "logical-mathematical theory of educational processes," which is based on the objective regularities of human psychology and physiology and a methodology of subject matters developed in accordance with the findings of contemporary theoretical logic. Solution of these problems will depend on the cooperation of the Academies of Medical and Educational Sciences with the Academy of Sciences USSR.

7. Gulyayev, P. [Doctor of Biological Sciences] Cybernetics of a living organism. Znaniye-sila, no. 11, 1958, 15-18.

During most of our waking hours we are busily sending and receiving information, using in the process all kinds of communication lines. Working as we do with information all our lives, we believe that we are free in our actions regarding both the sending and receiving of information. It never occurs to us that we are following stringent laws. We cannot infringe upon these laws with impunity. How can we determine the efficiency of these laws? If we try to talk increasingly faster, soon we shall find that there is a limit to fast talk; beyond that limit, our speech is no longer intelligible. The same holds true for a slowed-down speech. Thus, there is an optimum information-transmission rate which cannot be changed, which is the natural law of the informational process.

A communication pattern is universal; it includes a source of information, a transmitter, and a receiver. This pattern can be compared to what takes place inside our organism: the outside world is the source of information, the sense organs which transform stimulations into nervous impulses are the transmitters, the nervous impulse is a communication signal, the nerves are communication channels, and

the central nervous system is the receiver.

How can we measure information? Our first reaction would be to say that it is impossible. Information cannot be weighed or measured with a ruler. Changing now into the sounds of speech, now into electromagnetic pulses, radiowaves, or newspaper print, the information appears elusive, difficult to apprehend. It is nevertheless possible to measure it.

In our everyday life we are always faced with the choice of at least two possibilities: to turn left or right, to go up or down, to go forward or backward, etc. Sometimes, though, it seems that we are offered the choice of more than two courses of action.

Information has some interesting qualities. In spite of the various transformations to which it is constantly exposed, the information itself remains unchanged. Information transmitted by telephone originates as a psychic process—the thought of the speaker. This thought is then transformed into sound waves which act upon the membrane of a microphone. The information is transmitted by the mechanical vibrations of the membrane, which in turn give rise to electromagnetic waves in the telephone wires. The process of information conversion is then reversed and the information reaches the listener by way of sound. The listener understands the thought of the speaker, which proves that information, after passing through intermediate stages, remains unchanged.

Undistorted communication of information is accomplished by the nervous system of the human organism just as well. The information theory maintains that any information fed into communication channels can be coded by conventional signals. The coding process, which may seem to be a rather technical operation, is a common thing in living nature. All our life we are busy coding and decoding information. The simplest and the most convenient code is the one consisting of two signals. It should be noted that in the human organism information can be relayed not only by intermittent pulses of the nervous system but also continuously, namely through chemical communication channels such as blood.

What is the maximum amount of information a man can receive through his organs of hearing and sight? A man's cortex can receive through the eyes and ears 618 million information binites (information units) per second. The amount of information relayed by the eyes is 30 times greater than that which can be relayed by the ears. The information theory, while accounting for the quantity of information, does not touch upon the substance of the information relayed or its meaning to the receiver. Thus, in a 10-word telegram, we can make a

statement regarding the purchase of a book or, by using the same number of words, relate the news of the death of a good friend. The information theory, then, is not adequate to explain the principles underlying the activity of the nervous system.

The cortex does not deal directly with either the stimuli of the outside world, such as light, sound, heat, and cold, or the mechanical and chemical agents. All the various excitations which convey to the cortex the picture of the inside and outside world are transformed by sense organs into a single nervous process—nervous impulses. All nervous impulses, wherever they originate, are alike. There are no green or red, black or white, warm or cold, sweet or bitter, soft or hard, light or heavy impulses. This does not mean that all such impulses are absolutely identical. The impulses differ from each other with respect to the rate of propagation, the duration of flow, and other aspects. However, these are purely qualitative differences.

Why do we need a "living" telegraph? The nervous impulses feeding into the cortex are converted into controlling impulses and are directed through other channels to the organs of locomotion or inner secretion.

In human life, control processes are extremely important. We are hardly aware of the tremendous complexity of the motor system of our body. There are 639 muscles and 206 bones in our body, and the osseous "levers," "blocks," and "joints" have 105 degrees of freedom. When we stand, sit, walk, run, swim, write, and talk, strains in our body are continuously redistributed among the numerous muscles. Even without knowing which muscles to strain and which to relax, we are able to control our body confidently. The reason for this is that the body controls itself automatically. Cybernetics asserts the identity of control principles in the animate and inanimate world and helps us to achieve deeper insight into the essence of physiological processes. Physiology tells us how the telegraph in a living body is organized. Cybernetics goes one step further and tells us why it is organized this way and how it should be organized.

The amount of calcium contained in blood is likewise controlled in accordance with the feedback principle. In this case, however, information is supplied by a specific chemical substance, the hormone. This, in effect, is a chemical rather than a reflector line of communication. Consequently, chemical control is likewise subordinated to the feedback principle. Why does the organism constantly need to maintain a stability within its confines? The "free" life of the organism is conditioned by this stability. To be more specific, the stability of the internal environment of a body (homeostasis) is a prerequisite for normal mental activity.

Can an organism be controlled externally? The feedback principle has enabled us to explore brain areas which until recently had been unknown. As we know, the human brain is constantly generating electric energy in the form of electric current oscillations. The current changes at a frequency of 8—13 oscillations per second. Although the voltage of the biocurrents is one-millionth that of a local power station, it is very easy to measure these currents.

If we expose our eyes to a light which flickers 11 times a second, the electric current which develops in the cortex will have a frequency of 11 oscillations a second. By changing the flickering frequency from 4 to 60 times a second, we can induce electric processes of the same frequency in the cortex. By using an external stimulus, we can thus control the frequency of the electric processes in the brain. Cybernetics maintains that any control process can be entrusted to a machine, provided the principles governing such control are strictly adhered to. Gray Walter has shown that the researcher can be excluded from the control pattern and that the entire operation can be confided to a machine. This very principle is being used by doctors for making decisions of vital importance, for instance for determining whether a person is fit to test aircraft.

It has been shown that a flickering white light produces not only the sensation of flashes but a variety of illusions as well. A peculiar electric process, corresponding to a certain illusion, originates in the cortex. If the biocurrent resulting from this process is fed into the controlling machine, the process will be maintained and the illusion strengthened in accordance with the feedback principle. In this case, the machine acts as an illusion amplifier. Following this line of reasoning, we can assume that it may be possible some day to build a thought amplifier. The principles of cybernetics can even be used in controlling the sleep of animals and men.

The examples discussed here show that a great variety of phenomena can be included in a control process. Physical, physiological, and psychological processes can be included in a single chain. The different links of this chain are held together by the unifying feedback principle.

8. Gulyayev, P. [Doctor of Biological Sciences] Illness, reflex, and thought models. Znaniye-sila, no. 5, 1959, 13-15.

We know that a man deeply absorbed in thought frequently is unable to evaluate events objectively, acts hastily, and

makes wrong decisions. The biologists thus ask the question: what goes on in a man's nervous system when he is carried away, "blinded by passion?"

Experiments conducted with animals have proved that extreme excitation of the nervous center produces a delayed reaction in other centers, the result being a distortion of the analysis and synthesis of excitations. However, there are limitations in working with living models. Living models are extremely complicated organisms. This is the reason why biologists model biological processes and phenomena which do not reconstruct the whole complex picture, say, of an illness (which is different in each organism) but merely reproduce its outline.

It has long been known that many of the principles used in technology were "discovered" by animals millions of years ago. The oldest electric generators, for instance, are found in certain species of fish, and bats were the first to "make use" of radar.

Mechanical movements are always accomplished according to the principles of mechanics, regardless of where they take place, in living or dead nature. It is no wonder that mechanical engineering has acquired such companions as biomechanics, and even ballistic cardiography, a science dealing in heart activity from the viewpoint of ballistics. The laws of physics, chemistry, and even architecture, are applicable to any living organism. There is a special branch of botany, the architecture of plants, whose objective is to study the "structure" of plants. In addition, any organism reflects in its appearance and structure the environment in which it lives. Natural selection, through the process of elimination, has done away with various animals and plants which have not fully met the requirements of nature. On the other hand, a machine, to be efficient, has to be adjusted in its design to the medium in which it will operate. The "technical condition" required for a machine and a living organism are, as we have seen, alike in many respects.

Chemical models have proved convincingly that "living molecules" do not exist. This is one more argument against the idealistic concept of a special "vital power" inherent in the cells of a living organism. At the same time, it became quite obvious that life can manifest itself outside the body of an animal or plant.

All kinds of spare parts, from artificial bones and joints to heart valves, are finding application in medical practice. Artificial organs have shown that a model can be many times as efficient as a living organ. Artificial kidneys,

for instance, eliminate urea from blood faster than natural kidneys. This is explained by the fact that the rate of filtration depends on the extent of the filter surface. In natural kidneys, this surface is approximately 20,000 square centimeters; in artificial kidneys it can easily be twice this much.

However, steel hearts or plastic lungs are not the ultimate solution to our problem. We need artificial hearts, lungs, and kidneys made of live tissue. Research work is being conducted in this direction. Biologists are striving for configuration and heredity control.

The laws governing configuration are extremely important in the life of an organism. When these laws are mastered, man will be able to reshape his body and his inner organs to meet new requirements, for instance, to fly to other planets. The time will come when we shall be able to change our body just as easily as we change our clothes.

Any process, including the nervous process, can be modeled. This is made possible by electronics, which is penetrating deeper and deeper into the domain of biology. The Soviet scientist Ye. Babitskiy has recently built a rather complicated electronic device for modeling electric heart activity. An electronic model which reproduces the rhythm of nervous excitation and muscular contraction was developed by P. Gulyayev in cooperation with B. Shevelev in 1940. Excitation of a nerve and contraction of a muscle are vibration processes revealing rapid changes in the physiochemical condition of the nerve or muscular tissue.

Why does a machine need conditional reflexes? Like a living organism, the machine perceives outside information, remembers it, reworks it, acquires new experience, and forgets it. Are we to believe that the automatic "turtle" is nothing more than a funny toy? The answer is: definitely, not! Cybernetic "toys" provide us with tools with which to carry out experiments with the very principles of the biological sciences, in this case with the all-important temporary-communication principle. The fact is that in spite of the extensive research done so far, we still do not know how cortical cells are connected with each other during the formation of a conditional reflex. The nervous system is a complex switching system made up of neurons, which are special cells for the purpose of quickly reacting to and communicating changes in the environment, both internal and external.

The reflex is only one side of the many-sided activity of the nervous system. But couldn't we, proceeding in the same way, design a model for the most complex nervous process,



d-on

the process of thinking? Much progress has been made in the last few years in the process of trying to construct models of cognitive processes, and electronics has made it possible to come close to the solution of this fascinating problem.

We have in front of us a universal, automatic electronic computer. It solves the most difficult mathematical equations, translates from one language into twenty other languages simultaneously at a rate of thirty words per second, plays chess and checkers, and writes letters on any given subject. When man performs the same operations, i.e., computes, translates, composes, etc., nervous excitation and retardation processes are flowing through the cortex of his brain. The question then arises: do similar processes take place in the machine or does the machine think differently?

The point is that the physiologist does not know which cells are responsible for retardation, how the cells are interconnected, and where they are located. How does an engineer go about building a thought model? He analyzes the behavior of man at work, sets up rules for solving the problem, and works out the circuit diagram for the electronic machine. The layout of the thinking machine helps the biologist understand the work of the brain.

The American scientist Hebb maintains that the nervous system is made up of a collection of cells which are closely associated as a result of learning. The learning involves the firing of a set of cells which originally may be in a fairly randomly organized state. Cells excited in the visual cortex are actuated by some visual stimulus A, say, and this set will have many cells in common with the assembly activated by other visual stimuli B, C, D. These cell assemblies, through fractionation and recruitment, or growth, become differentiated and highly organized. "Phase sequences," or pulsations of cell assemblies occur, mirroring the activities of perception and learning.

Milner assumes that cell assemblies and phase sequences occur according to the neural postulate as suggested by Hebb. He says that a cell assembly, after being under direct control, is under indirect control for some minutes, and A has either latent or active trace associations with B and C. The word "priming" is used to describe the lowering of threshold that follows the stimulation of a cortical cell by an afferent impulse; the effect is supposed to last only a few seconds. The sensory projection areas of the cortex are final distribution centers of sensory impulses, and the organism ignores stimulation if the cortex is already very active. But if the cortex is not very active, and the stimulus is very strong, then the activity of the cortex will be significantly changed.

Cybernetic machines were devised to check the two hypotheses. An electronic model was designed first according to Hebb's system; it did not confirm his hypothesis. The model was then redesigned according to Milner's theory, with the result that assemblies of active and latent neurons occurred, and the excitation wave appeared to move along the cortex. Milner's theory could be correct, but a definite statement to that effect, however, cannot be made yet.

9. Gol'dburt, S. N. [Candidate of Biological Sciences] Study of brain excitability. *Nauka i zhizn'*, no. 8, 1955, 27-29.

Man's central nervous system is made up of 10 billion neurons, and the complexities involved in possible combinations and recombinations of such a number almost defy the imagination. The cerebral cortex is thought to represent the controlling center of all behavioral activities, and it is this complex layer of neural cells that has been the object of recent investigations.

What is the correct approach to the study of excitability of a human brain? When we speak of excitability, we normally think of the ability of a living organism to react to external stimuli. But how can we measure man's capacity for seeing, hearing, smelling, i.e., in the words of I. P. Pavlov, how are we to discriminate among the complex manifestations of the world surrounding us?

We cannot yet visualize an accurate pattern of the processes taking place in a human brain, but we do have the power (using test stimuli) to "look into" it, to ask questions. The answers to these questions are anything but simple and it is up to the physiologists to make out what they mean.

It is quite apparent that the electric-irritation method cannot serve as a basis for a systematic study of brain activity. Such observations are feasible under exceptional conditions only. Besides, they yield information which is very general and tentative. This is why physiologists and doctors are searching for other means for studying excitability.

The cerebral cortex generates several types of electrical oscillations:  $\alpha$ -waves, having a rhythm of 8—10 oscillations per second and a voltage of 0.5—0.9 mv; and  $\beta$ -waves, with a rhythm not exceeding 50 oscillations per second and a voltage of 0.13 mv. When subjected to light, sound, and other irritations, and during periods of mental strain,  $\alpha$ -waves become weak and irregular while  $\beta$ -waves gain in strength and

frequency. Another source of information with seemingly enormous potentialities is the electroencephalogram (EEG). Emotional tension changes EEG patterns and helps doctors to diagnose an illness.

The excitability of the brain is determined by the level of its response to outside stimulation. It has been inferred that different strengths of stimuli elicit quite different levels of response. In the search for adequate means to investigate brain excitability, Academician P. P. Lazarev was the first to suggest eyesight as the subject of a special study. He did this on the grounds that the retina is but a peripheral section of the brain. Since the sight organ is one of the main factors enabling man to "orient himself" in the outside world, we can safely assume that any change in brain activity would be reflected in the excitability of the eye; and vice versa, any stimulation of the sight organ would affect the excitability of the brain. This assumption was confirmed by tests conducted by Professor S. V. Kravkov, Professor P. O. Makarov, and other Soviet Scientists.

Professor Makarov has constructed a special device, an optical adequatometer, which measures the intensity and duration of light irritation and the minimum time interval (the critical interval of darkness) between two light flashes a man can perceive. Experiments carried out with this device have shown that attention and increased cerebral activity are associated with shorter adequatometric intervals, while exhaustion and decreased cerebral activity are correlated with longer time intervals. From another series of tests, conducted by Professor N. I. Leporskiy and Professor A. L. Landa, it was inferred that in the case of an incurable illness the adequatometric interval may for years remain constant at 200—300 msec. A man's recovery is normally accompanied by a reduction of the time interval, i.e., by increased brain excitability.

The first adequatometer used to study optical excitability was a rather large laboratory apparatus that had to be mounted in a specially equipped room. In hospitals, however, doctors are trying to bring as little inconvenience to the patient as possible. With this aim in mind, Professor Makarov has designed a small, portable instrument, weighing 5—7 kg, which makes it possible to conduct observations on patients confined to bed. This method is now being used in a number of clinics and institutes in Moscow, Leningrad, Smolensk, Frunze, Gorky, and other Soviet cities.

10. Latash, L. P. The governing centers of the brain. Nauka i zhizn', no. 4, 1962, 65-7.

The article deals with various regulatory functions of the central nervous system. The basic governing organ, according to the findings of neurophysiologists G. Megoun (USA) and D. Moruzzi (Italy) is the reticular formation in the central part of the brain. All signals received from the outside by the sense organs are stored and "evaluated" in this formation before they reach the outer parts of the brain for information, and "action", if necessary. The general function of the reticular formation, however, is to keep the nervous system in a state of alertness, i.e., awake. Every new, unexpected development is transmitted with stressed urgency as an alarm or, to use Pavlov's term, an "orientation reflex." In the same way, the formation can filter out all information irrelevant to the particular circumstances and concentrate on facts of special interest or importance. This is made possible by interconnections between its cells, which render the system a pulse multiplier. Feedback is realized through a multitude of closed circuits of various size and complexity. An outside signal, through multiplication and feedback, can keep the system in an excited state for a period of time, which itself can be determined by a command from above. Thus, the system can be "tuned" to a specific kind of information and made insensitive to other signals. Under normal conditions, the reactions of a living organism are smooth, definite, and exact. Disturbances in the multiplication system, delay in feedback, etc., result in inexact, delayed, or erratic reactions, i.e., reactions which are not fully controllable. A case in point is Parkinson's disease.

A very important, often decisive, role can be assigned to the feeling or anticipation of "pleasure" in shaping the character of actions. Although this mechanism is not understood, its malfunction is assumed to be responsible for certain psychic disorders, such as schizophrenia, and some types of psychoses and neuroses. The functioning of the brain, if compared to the trial-and-error method used in computers, is a less exact but far more efficient and economical system. Its "trials" are not random but are selected on the basis of past experience according to their relevance; the selections are at the same time parts of a preconceived plan of action accounting for the most important factors known.

The brain system has been investigated analytically by mathematician I. M. Gel'fand, Corresponding Member of the Academy of Sciences USSR. The experiments of the American neurophysiologist K. Pribram with monkeys are referred to as confirmation of the theory. The Soviet physiologists P. K. Anokhin and N. A. Bernshteyn are mentioned as early pioneers in the investigation of regulatory functions of the brain. Subsequent achievements in the field of neurophysiology are ascribed to I. P. Pavlov. At present, the functioning of

the human brain is a subject of interest in mathematics, psychology, medicine, linguistics, etc.

In general, the functions of the brain can be divided into two categories: the operational and the regulatory. Both are closely interrelated, and the highest command level is at the same time subject to governing by its special mechanisms. The understanding of this unique creation of nature, though far from complete, has already led to significant practical applications, such as the location of psychic troubles in the brain and their treatment by chemical and electrical means. Its impact on the technology of cybernetics will be no less significant. New types of electronic modeling machines capable of copying certain mechanisms of the brain open new possibilities in the automation of production and mechanization of brainwork.

11. Kiy, V., and Yu. Sundukov [Scientific staff, Computing Center of the Academy of Sciences Ukrainian SSR]. Bioelectrostimulation. Nauka i tekhnika, no. 7, 1962, 40.

The origins of biocybernetics are reviewed. Stimulation by means of control signals is discussed from the standpoint of reestablishing damaged connections between nerves and the central nervous system and the study of the heart and lungs. A group of physicians, headed by one of the originators of the bioelectrostimulation method (Senior Scientist G. F. Kolesnikov of the Computing Center of the Academy of Sciences Ukrainian SSR) is conducting a study of the possible application of biostimulation in healing various neuromuscular and organic diseases.

12. Laska, Ya. [Senior Engineer, Institute of Electronics and Computer Technology, Academy of Sciences Latvian SSR]. The symbiosis of man and machine. Nauka i tekhnika, no. 4, 1962, 11-12.

A computer must be geared effectively to the thinking processes of a man. It is expected that in 10--20 years all symbiotic functions will be carried out at "thinking centers." These centers will be linked together and to research centers, schools, etc. Complete and effective symbiosis of man and machine is hampered by the printout (readout) rate and by control devices. It is envisaged that in the future, man and machine will draw graphs, make calculations, write equations, etc. Voice contact between man and computer is a problem which is being considered. A dictionary consisting of approximately 2000 words (1000 high-frequency words and 1000 technical words) would be required for such contacts.

13. Arin', E. [Candidate of Physicomathematical Sciences, Director, Computing Center of Latvian State University] The machine can be programed. Nauka i tekhnika, no. 4, 1962, 18-19.

Electronic computers are capable of performing, to a certain extent, creative work without being programed. The use of a random signal oscillator for modeling a random search is described. A comparison is made between the capacity of a human brain ( $15 \times 10^9$  cells) and that of a machine (several thousand electronic tubes and semiconductor elements). It is concluded that computers will probably replace man for the performance of "narrow, specialized" administrative tasks.

14. Kyuni, I. Fifteen billion brain cells. Nauka i tekhnika, no. 2, 1962, 28-30.

Phrenology, introduced by Gall in the 19th century, is dismissed as being without scientific validity. The human brain is described as an organ for the control and coordination of all bodily functions which are stimulated by psychophysiological processes. Attention is given to the cell (neuron) structure of the brain, neuron bioelectric activity, and the practical significance of electroencephalography. The use of miniature electrodes in electrocortigraphy is discussed. A new pure science has been developed from the method of induced potentials (nerve impulses in neurons due to the stimulation of a certain part of the body or nervous system). The possibility of artificial stimulation of psychological processes by means of currents through microelectrodes is envisaged. In this line of research reference is made to the experiments by Professor Jakobsen (Oslo) which were disclosed at the Congress of Neurophysiologists in Paris (1960). Reference is made to similar experiments by Dr. Batton (United States) in 1957.

15. Kol'man, E. [Academician, Director of the Institute of Physiology of the Czechoslovak Academy of Sciences] Can machines have a psyche? Tekhnika molodezhi, no. 1, 1962, 24-26.

Kol'man devotes almost the whole of his article to a point by point refutation of an earlier speculative article by the mathematician, Academician Andrey Nikolayevich Kolmogorov. Kolmogorov believes that machines may someday be built which will be able to experience emotion, possess a will, and engage in independent thought. Kol'man feels that even if artificial living intelligences can be created, there is no reason to suppose that they will share with man

any of the characteristics of human personality. His attitude is compounded of orthodox Communist mistrust of the concept of the psyche, and an unwillingness to speculate irresponsibly.

In his conclusion, Kol'man defines the role of cybernetics as three-fold, and defends it against its "enemies," who wish to limit it to a science of mechanical automation. (An enemy of cybernetics is one who passes off his unwillingness to learn and master the new methods and apply them in biology, medicine, and psychology, or even to develop a reasoned philosophy of cybernetics by way of participating in the struggle against "mechanicism".) Kol'man would not limit cybernetics to mechanical applications only; he sees it as having legitimate applications in three fields: mechanics, the life sciences, and the social sciences. The three-fold role of the progressive science of cybernetics is thus: 1) to free man from monotonous and repetitive physical and mental labor, 2) to serve the biological and medical sciences, and 3) to collaborate with psychology and pedagogy. As a partisan for the advancement of cybernetics, Kol'man is all the more dismayed to see well-meant but possibly "harmful, fantastic nonsense" issuing from so eminent a mathematician as Kolmogorov.

16. Myakushkov, V. Cybernetics of the brain. Tekhnika molodezhi, no. 1, 1964, 30-31.

Among the developments reported by the Institute of Cybernetics of the Academy of Sciences Ukrainian SSR is a cybernetically synthesized structurally simplified model of a neuron, capable of reproducing all nuances of the behavior of this basic unit of the mind. Modeling of an entire brain is still not feasible; even the crudest neuristor is about equivalent to a fairly complex radio receiver circuit. Nonetheless, models of aggregates of dozens or even hundreds of neurons are planned, as a step in the exploration of thought processes in all their multiplicity and complexity.

One obstacle to the creation of an artificial brain is that of size. Already, however, miniaturization has produced printed-circuit storage devices a few square millimeters in size and having a 500-600 bit capacity. The day is predicted when miniaturization will make possible a brain model approaching an actual brain in compactness. Meanwhile, electronic modeling methods are aiding biologists in studying the brain on the individual cell level, in order to verify hypotheses concerning the transmission of information from neuron to neuron and investigate the processes of stimulation

and fading of conditioned reflexes.

Automation of mental labor is another goal of cybernetics. The objective is not only to free man from routine data processing tasks, but to produce machines capable of classifying and retrieving information far more accurately and reliably than can be done by the most highly qualified human specialist. Cybernetics has also provided the possibility of conducting mathematical experiments on a scale hitherto unknown. Computers are capable of proving any theorem, if it is in principle provable, no matter how laborious the proof. This means that many theorems hitherto accepted without proof can now be demonstrated. Machines are even being taught to distinguish between sense and non-sense, to distinguish sentences like "the stork is writing" from "the stork is flying," i. e., to bring similar concepts together into one class and precisely define that new class.

The Institute of Cybernetics of the Academy of Sciences Ukrainian SSR, which is located on the outskirts of Kiev, is directed by Vice-President and Member of the Academy of Sciences Ukrainian SSR, Viktor Mikhailovich Glushkov. Yuliya Vladimirovna Kapitonova and Aleksandr Adol'fovich Letichevskiy are among his research assistants.

17. Napalkov, A. V. [Candidate of Biological Sciences] Cybernetics and the brain. Nauka i zhizn' no. 6, 1962, 48-49.

A few years ago the work of the human brain was one of the best guarded secrets of nature. Today, we already have models which make it possible to simulate some of the complex functions of human behavior.

Numerous international conferences have been devoted to problems concerned with the application of the operating principles of the human brain to cybernetics. One of these conferences, held in Karlsruhe, West Germany, in April, 1961, dealt with self-learning automata. Newell, Shaw, and Simon (USA) have devised a new method for studying the cerebrum wherein complex brain activity is broken down into a number of elementary information processes. Gramer and Wenzel (West Germany) reported on perception and cognition processes. The problem here was how to "teach" a machine to read and to understand spoken words. Doctor Rosenblatt reported on a machine capable of conceiving the simplest abstract notions, such as a square or a triangle.

Another international meeting of cyberneticians took place in Namur, Belgium, in September, 1961. Problems dis-



cussed at this meeting included control processes within the human body, the theory of the development of psychoses, the construction of a hypnotizing machine, and control systems involving biochemical processes.

18. Napalkov, A. V., and N. A. Chichvarina. Control systems and the health of man. Priroda, no. 12, 1964, 31-38.

While visiting Moscow, Norbert Wiener was asked which part of cybernetics he considered to be the most important. His answer was: "First of all, the study of self-organizing control systems and the problems related to life as such, but these are just different ways of expressing the same idea." Life is closely related to a complex control system operating within the organism. Any disturbance of this control results in illness.

It becomes increasingly obvious that a large number of diseases are due to the development of new control mechanisms which actively support harmful "deviations from the normal" in the activity of a man's inner organ. Why does our nervous system act this way?

When trying to answer this question we invariably run into the theory of self-organizing control systems. Such systems are thought of as being systems capable of developing new programs; i.e., devising new control mechanisms. A control device normally receives information about the inner organ under its control and sends back new messages or commands. If, for instance, a signal reaches the brain, telling it that the blood pressure has risen above the "standard level," then the brain sends back the instruction: "slow down the work of the heart." This is what we call the feedback mechanism. Wiener believes that any self-organizing control system is based on a set of algorithms (a synonym for decision procedures). Academician A. A. Markov, one of the founders of the theory of algorithms, defines the algorithm as the key to a lock, the lock being the problem to be solved.

An algorithm is not merely a set of rules or a summary of reflexes; it is a self-contained system in which the sequence of control operations plays an important role, and which makes provision for the deviations which are bound to occur in complex situations. An important fact is that algorithms are built upon interdependent levels. The first such level is the control program, i.e., the system of commands which directly controls the activity of the inner organs. The second, higher, algorithm is a system of rules

and principles which produces new control mechanisms and supervises their operation. It is thus apparent that the second algorithm is chiefly responsible for the well-being of the human body. The work of this algorithm is guided by the third-level algorithm.

It is emphasized that in cybernetics algorithms have been used to study the work of the central nervous system. Scientists know by now how this or that algorithm operates as well as what phenomena should occur if the control mechanism employs this or that algorithm. Consequently, if an algorithm description can be given for brain activity, scientists could use the whole algorithmic theory now available to them. An electronic model could then be constructed which would illustrate the progress of a disease and indicate the means for combating it. Effective treatment of a disease will become a possibility as soon as methods are devised to directly affect the control mechanisms. This is where cybernetics can play a decisive role. We know that I. P. Pavlov had placed great emphasis on the study of control mechanisms. Before Pavlov, a disease was normally thought of as being an affection of individual organs and tissues. The Russian physiologist was the first to investigate the way the nervous system controls the activity of the inner organs and affects the spread of a disease. K. M. Bykov and A. O. Dolin, both students of Pavlov, pointed to the possibility of generating conditioned reflexes, including the pathologic conditioned reflexes, bearing on the activity of the inner organs.

In order to build an automaton that would control the operation of a relatively small enterprise, the engineer has to work out a complex electronic scheme, to use the complex principles underlying the control and communication theory, and to devise algorithms. The work of a living organism, however, is hundreds of times more complicated, and the control processes here undoubtedly are much more complex and much more perfect than those employed in engineering. Along which lines can we then apply cybernetics in medicine?

We are faced here with two main problems: a full description of control algorithms and an analysis of the structure of control mechanisms. The discovery of algorithms is the cardinal problem in any control system. Modeling is definitely of great help in solving this problem. Further development of the theory of algorithms is very important also. The other problem concerns the structure of the control systems. We know that the basic properties of any automatic machine are determined by its structure. When studying brain activity, we face a similar problem. We can hardly assume that a highly complex control could be effected simply by a summary of reflex arcs or intermittent contacts

(synaptic junctions) between the cells. How should we then go about analyzing the structure of the brain neurons? A direct investigation of the brain would lead nowhere even if we employ the latest methods devised for that purpose. Cybernetics resorts to the "circumvention" method, i.e., it approaches the problem from the rear.

A neuron is a specialized cell with an especially high degree of irritability and conductivity. There are various neurons in the nervous system which may differ from each other greatly in size and sensitivity. We cannot artificially combine these neurons and study the new properties which originate from such combinations, although this seems to be the right approach. What we can do, however, is to design neuron models and carry out artificial syntheses with these models. This problem falls into the realm of theoretical neurology, or the theory of neural nets.

19. Teplov, L. Brain and machine. Tekhnika molodezhi, no. 2, 1959, 5-6.

I. P. Pavlov compared the work of a human brain with that of an automatic telephone exchange. Today's electronic computers suggest a much closer resemblance to the human brain, whereas a telephone exchange "remembers" only those signals which effect a rearrangement in its circuitry, and "stores" the signals only up to the time of the next switch. The electronic computer can store in its memory device any signals indefinitely. This is realized in particular by the use of closed circuits, or delay lines, in which combinations of impulses can circulate for an indefinite period of time.

A similarity exists between nerve cells and the elements of an electronic computer. The triggers in a computer can send messages in one direction and receive two opposite (extreme) conditions: switched in—switched off, yes—no, excitation—inhibition. In addition, digital computers, now constructed for a variety of different purposes, are capable of adding up numbers, sorting and classifying information, and making predictions based on forms of induction. Such machines have sometimes been directly described in logical terms.

The work of both the brain and the electronic computing machine is made possible because all kinds of information and commands can be expressed in correlating signals. For instance, sounds and optical images can be converted (by microphones and iconoscopes, respectively) into electric signals which can in turn be converted into any of the states readily

lending themselves to identification. Work on automatic translation, solution of chess problems, and many other applications of electronic computers, have revealed a striking similarity between the functions of the machine and those of the human brain. Nevertheless, it is safe to say that a modern computer does not operate in the same manner as a human brain.

The electronic computer has two different memory stores: 1) a dynamic, high-speed counting store associated with perception and recognition, and 2) a static, more permanent store for recording the machine's experiences. If we could design a machine in which signals would continuously shift over the trigger cells, such a machine would resemble the brain more strongly. If we fill in all of the memory cells of a computer with signals, the computer would no longer be able to receive information. Obviously, the most interesting feature of the brain is that it continuously compares signal combinations stored in it in an effort to establish as economically as possible their relationships and to release the memory for new information. In the information theory this is called "the increase of information contents." During his lifetime, man receives such an enormous quantity of signals that billions of signals would not be sufficient to store them in their original form. Generalization of relations between signals by eliminating repetition appears to be the principal goal of the logical activity of the brain. Also, the human brain stores in its memory information about its own actions. Nothing like that can be found in an electronic computer.

The author rejects the idea that the brain can be regarded as a computer-type control system. But, just as a general-purpose digital computer can be shown to learn and to behave inductively, if suitably programed, so does the cortex receive commands and assignments from the body and the underlying parts of the nervous system. Without these commands the work of the brain would be pointless.

20. Teplova, L. Steps toward a model brain. Tekhnika molodezhi, no. 1, 1964, 31.

Neuristors are required to duplicate fully and exactly all functions of a living nerve cell. One of the most complete models so far devised, built by the Institute of Cybernetics, Academy of Sciences Ukrainian SSR, utilizes four semiconductor triodes.

If a system of cells rather than a single cell is modeled, new and interesting properties appear. Such a model can distinguish between sense and nonsense in

language, on the basis of stored information on the probability of occurrence of combinations of words, syllables, or sounds. On the basis of their frequency of repetition, all possible combinations of words and parts of words are assigned a probability, ranging from "almost mandatory" (wide paths) to "impossible" (dotted lines). These combinations are analyzed on three levels: combinations of letters forming syllables, combinations of syllable forming words, and combinations of words forming sentences.

21. Pekelis, V. Can a "thinking" machine solve any given problem? Tekhnika molodezhi, no. 4, 1959, 8-9.

High-speed electronic computers, developed some 15 years ago, are capable of solving the most complex mathematical problems, playing a game of chess, making translations from one language into another, controlling industrial production processes, and guiding trains and aircraft. What, then, is the limit to what an "intelligent machine" can do?

In 1937, A. Turing, an English mathematician, developed the concept of a rather simple automatic computer. As conceived, the machine consisted of a length of tape which could be as long as was wished, and therefore potentially infinite. The tape could be marked out into squares onto which symbols could be printed. The body of the machine was conceived as a scanner that would scan one at a time the squares containing the symbols. The machine theoretically could alter the symbol on the scanned square, move to the right one square, move to the left one square, or stop, according to the instructions making the program. The symbol scanned, together with the internal configuration of the machine at the moment of scanning, would decide the next operation to be performed.

The Turing machine was never built. Indeed, it was unnecessary to build it. The machine is a "paper machine," and is mainly of interest from the standpoint of what machines are capable of in principle. One thing that should be made quite clear is that although a Turing machine would be capable of making all machine-like computations, it would require a long time to do the more complicated operations, and so would be extremely wasteful of time. What seems to be of vital importance for the theory of machines is this: whatever can be done by humans can be done by machines, provided that an adequate description is available of what the system to be mirrored actually does.

The Turing machine shows how, using such a description, or algorithm, the most complex process can be broken down

into simple and monotonic operations. Paper machines tell us a great deal about the nature of machine construction and which thinking operations are possible, and about the construction of nervous and other biological systems and their possibilities. The main point is that it is not possible to build all the machines we would like. But this we now know definitely: we can automate only those processes for which blueprints can be made available. In other words, if the details of any machine whatsoever are printed on the tape of a Turing machine, then it will be able to carry out the operations of the machine so described. This means that all machines are, in a sense, reducible to a universal Turing machine.

22. Saparina, Ye. The human brain—a computer? Znaniye-sila, no. 12, 1962, 34-37.

A comparison is made between the functioning of the human brain and the operation of a modern computer. The author attempts to show the areas in which the central nervous system is superior to the computer, and thereby to indicate the direction which should be followed in the further development of computers. The modern computer still uses the simple trial-and-error method in finding the correct solution to a problem, while the human brain, even in its simplest functions, employs the method of "localized search" or "sampling." In "localized search" the result of the first trial is more precisely qualified than just by the "yes" or "no" of the trial-and-error method, and the outcome of the analysis of previous trials localizes the subsequent trials more and more closely until the best solution is found. Localized search is good only for performing simple movements. The actual situations which must be mastered by the human brain require more perfect methods, methods which at least discriminate between the functions of first, second, etc., degrees of importance. The first trial, which can be defined as a "random step," is followed by a second which is based on the analysis of the result of the first; the comparison of both analyses usually determines the third step, which will be a good approximation if not the solution. The success and speed of this "random walk" method depend greatly on the length of the steps chosen.

The "random walk" method is reflected in a theory developed by Soviet mathematicians I. Gel'fand and M. Tseytlin. Further knowledge of the functioning of the human brain has been derived from experiments conducted by Professor V. Gurfinkel and M. Tseytlin in the new Laboratory of Biological Cybernetics [probably of the Institute of Biophysics]. These two researchers made investigations of the maintenance of the

vertical body position by man under various conditions. Observations of the position of the body's center of gravity revealed that balance is maintained by a complex system of reactions to minute deviations from the position of equilibrium. The record of fluctuations of the center of gravity showed at least three different mechanisms operating, each with a distinct and stable frequency. The character of the summary curve reflected the "random walk" method by displaying periodic fluctuations with smooth rises followed by step-wise drops at a much higher frequency.

It is concluded that the human brain works in a manner similar to a modeling device except that it operates with physical magnitudes. But the brain is a multistage regulating device, and only its very lowest stages use the methods described. The higher stages involve much finer analysis, taking into account more distant factors, establishing the trends of future development, and creating the models anticipating its own reactions and their probable results. In addition to governing an operation, the brain is also involved in the strategy and tactics of behavior. Reference is made to the experiments of the American neurophysiologist K. Pribram, who demonstrated that monkeys show a marked capacity for "accumulating experience" or "learning from experience." Experiments with humans carried out by physiologist M. A. Alekseyev in the Institute of Higher Nervous Activity further demonstrated that even in the application of the trial-and-error method for finding the sequence of random numbers the human brain departs more and more from purely logical methods in the course of its operation and thereby reaches solutions faster than computers, whose methods are strictly logical.

23. Saparina, Ye. White spots on the brain map. Znaniye-sila, no. 1. 1961, 10-13.

Whenever someone wants to illustrate the difference between a modern cybernetic machine and a living brain, he points to the number of electronic tubes and nerve cells which they "represent." The difference is astonishing, indeed. The human brain contains at least 1 million times the amount of "nerve cells" in a standard electronic computer. Furthermore, if it were possible to build a computer with as many electronic tubes as there are nerve cells in the brain, the energy required to operate such a computer would exceed the energy supplied by the water resources of Niagara Falls. Another Niagara Falls would be needed to cool the tubes. In contrast, the living, thinking brain consumes only as much energy as a 25-watt electric bulb. All of this energy, however, is used to full advantage.

The quantity of working cells in a computer is not the important factor. A computer does not necessarily have to be "stuffed" with electronic tubes. Machines have already been designed which surpass the brain with respect to both the size and quantity of elements. The important thing is that in an electronic computer each "cell" has 4 or 5 connections at the most, whereas the brain has innumerable connections that enable it to react far more intelligently.

The so-called topographic brain maps which have been developed recently show 52 areas which vary with respect to structure and purpose.

There is reason to believe that the frontal lobe area is used primarily for comparing different perceptions. Logical relationships between concrete communications and generalized, abstract notions are believed to be formed here also. The frontal lobe is thought to be the storehouse for the most important information on previous perceptions and actions. Man does not have a separate "memory unit" like the one built into an electronic computer. At any rate, a special mechanism responsible for the storage of nerve signals in the brain has not yet been discovered. Experts in cybernetics believe, and not without reason, that we know today no more about the nature and location of our memory than did the ancient Greeks, who considered the pectoral diaphragm to be the seat of our mind.

Not so long ago, physiologists discovered in the brain a rather curious device which seems to be in charge of "recalling" certain information from different sections of the memory. This subcortical structure, unlike the cortex, consists of groups of nerve cells that are not layered above each other but are spread in a thin network over the entire brain. They are even called the reticular structure. Soviet physiologists, headed by Professor P. K. Anokhin, a disciple of I. P. Pavlov, have had great success in exploring this structure. After a careful study of the electrical phenomena occurring in the reticular structure, scientists concluded that signals entering the cortex from that network act as stimulators. The "awakened" cortex is then capable of perceiving signals arriving from the sense organs and extracting from the memory the information needed.

The reticular structure should only be regarded as an auxiliary device, as a decoding center and amplifier for incoming signals. It can be assumed that signals from this center inform the cortex that various requirements of the human body (e.g., food, water) have been fully satisfied.

If the reticular structure is some kind of a general-alarm device, then the "pleasure center," located in the



central brain, could be viewed as a guardian which informs the brain that everything in the organism is in order.

The development of our knowledge of the reticular system is extremely relevant to our understanding of the problem of attention and alertness, and also perhaps of consciousness.

According to the latest information available, the brain appears to be a mechanism much more complicated than any of the cybernetic machines being designed today. We can speak of a similarity between the brain and electronic computers only in terms of their operation, not in terms of their structure.

24. Taryan, Rezhe [Doctor of Technical Sciences, Budapest]. Problems of cybernetics [A translation from the German by Z. A. Filanovskaya]. Priroda, no. 6, 1959.

The author analyzes the relationship between the regulatory and control mechanism in live organisms and in technology. While biologists are concerned with understanding an existing system, the engineer's task is to create new systems which do not exist in nature. On the other hand, the technological systems are much more primitive than those existing in live organisms, although the basic principles appear to be essentially the same. Cybernetics, from the viewpoint of an engineer, is an attempt to supply the organization of live organisms to the technology of regulatory and control systems. The work of neuro-anatomist Janos Szentagostai and mathematician Alfred Renyi, who studied neurons and their functioning in quantitative terms, is outlined.

The system of interconnection between the neurons and their network is described in general terms. Two properties of living organisms must be reproduced in technological systems: 1) the capacity of maintaining the system as close as possible to the given criterion, and 2) the capacity of operating without failures, i.e., to be trouble-free and fully reliable. The first problem can be solved by computers, which continuously receive information concerning the actual condition of the system and which turns out a steady succession of commands to adjust the system to the required standard of operation. Soviet scientists A. Ya. Lerner, A. A. Fel'dbaum, M. A. Gavrilov, and V. S. Pugachev are said to have achieved important results in this area.

25. Shcherbak, Yuriy. The neuron began to speak. Nauka i zhizn' no. 6, 1962, 50-53.

Staff members of the Laboratory of General Physiology

of the Kiev Institute of Physiology im. A. A. Bogomol'ts, Academy of Sciences Ukrainian SSR, under the supervision of P. G. Kostyuk, were the first in the Soviet Union to gain an insight into a neural cell, the neuron. They recorded its "voice" on tape and photographed its impulses. A neuron is a specialized cell with an especially high degree of irritability and conductivity. It is the seat of complex biological processes. It also generates electric energy, its electric potential being made up of positively charged cations and negatively charged anions. Scientists have shown that this potential is essential to the viability of the cell.

For naturalists, the investigation of the behavior of a neural cell is a breakthrough into a new, still unknown, world. Such an investigation may be compared with the structural analysis of an atom by physicists. Once we understand the "mechanics" of a neuron we will know more about some of the grave and incurable diseases of the nervous system.

By introducing a microelectrode inside a nerve cell, P. G. Kostyuk was able to show the reaction of the nerve cell to excitation, and to measure certain parameters of the impulse. He also conducted a set of experiments with the object of trying to understand the chemistry of cell membrane formation.

It is hoped that as soon as we learn more about the electric processes that are known to occur commonly in a neuron, we shall be able to unravel the mystery of the surprisingly accurate, rapid, and economical system of information processing and transmission in the nervous system. Transmission of information in the nervous system is thought of physically as being an infinite amount of vibrations of the neural electropotential. The implication that all parts of the neural system, as well as the whole organism, could be studied from the point of view of information is clear, for the brain is without doubt an information-receiving, -transmitting, and -storing system. Electrophysiology can therefore contribute much to our understanding of biological functions, as has been done by I. M. Sechenov, N. Ye. Vvedenskiy, A. S. Samoylov, V. Yu. Chagovets, and D. S. Vorontsov.

Today's testing equipment may very well be replaced in a few years by miniaturized devices, and the use of new microelectrodes may completely resolve problems involving nerve tissue.

26. Shcherbak, Yuri. A neuron speaks out. Nauka 1

zhizn', no. 6, 1962, 50-53.

A report is made on the work of Platon Grigor'yevich Kostyuk, Doctor [of Biological Sciences?], who is associated with the Laboratory of General Physiology at the Kiev Institute of Physiology of the Academy of Sciences Ukrainian SSR, and other electrophysiologists at the Institute. It is claimed that researchers from this institute were the first in the Soviet Union to penetrate inside an isolated neuron, to record its "voice" on tape, and to print on film weak electrical "dramas" which are stamped inside the cell. Neurons are unique generators of electrical power. A neuron is compared to an autonomous territory with its own electrical potential (cations on the surface and anions inside the cell). The presence of potential is an important sign of neuron viability. Penetration inside a neuron is very difficult. Special glass microelectrodes (needles), made in Kostyuk's laboratory, were used for this purpose, and the output from a neuron was recorded on an oscillograph. A qualitative analysis of the functional mechanism of a neuron is given. In his study of a single nerve cell, Kostyuk and coworkers obtained a series of mathematically exact, substantiated data. The microelectrode methods used in Kostyuk's laboratory have elevated physiology to the ranks of an exact (pure) science. These methods can be applied to an objective study of physiological processes inside a neuron and can control the ionic composition of the cell. Salts of sodium, potassium, and other elements can be introduced into neurons by means of microelectrodes. However, the small diameter of the microelectrodes will not sustain salt solution pressures of the order of several atmospheres. To overcome this difficulty, the ionophoresis method is used, i.e., polarized currents are passed through the electrodes. Two- and multi-channel microelectrodes are currently being used. Control of the ion charge inside a cell constitutes a useful tool in the control of complex nervous processes. The latter is of great interest to engineers concerned with information transmission. From the physical standpoint, information transmission is in the form of numerous oscillations of the neuron electropotential. Important contributions in the field of electrophysiology have been made by I. M. Sechenov, N. Ye. Vvedenskiy, A. S. Samoylov, V. Yu. Chagovets, and D. S. Vorontsov. Professor Kostyuk believes that study of a simple cell is only the beginning. In the future, simultaneous analysis, using thousands of electrodes, of a set of neurons is envisaged. Microminiaturization of equipment for this purpose holds the key to the problem.

27. Yakubaytis, E. [Corresponding Member of the Academy of Sciences Latvian SSR, Director, Institute of

Electronics and Computer Technology of the Academy  
of Sciences Latvian SSR] The machine and the brain.  
Nauka i tehnika, no. 8, 1962, 7-9.

The development, goals, and problems of cybernetics are traced and discussed in the light of Marxian, Leninist, and Pavlovian teachings. The experiments of B. V. Ognev, Corresponding Member of the Academy of Medical Sciences USSR, are described. These experiments deal with the subject of nerve modeling with metal wires. Certain nerves in canine specimens were replaced by platinum and tantalum wires. The test subjects functioned normally. The effect of control signals on limbs, an experiment performed by G. F. Kolesnikov (Nauka i tehnika, no. 7, 1962, 40), is described. The creation of an artificial brain is dismissed as being impossible.

28. Amirov, R. The brain lights up stars on an oscillator screen. Tekhnika molodezhi, no. 4, 1965, 8-9.

In an interview, Rasim Zakareyevich Amirov, Candidate of Medical Sciences, traced the history of thought propagation over distances, and discussed the development of the biocurrent idea. Professor M. N. Livanov and Engineer V. M. Anan'yev have developed a new instrument for the simultaneous recording of biocurrents from 50 points in animal or human brains. The instrument, which operates on the principles of television, is called a "brain TV set" and is capable of recording variations in thought patterns. The instrument, however, is not capable of reading man's thoughts. It has already been applied to the study of conditioned reflexes. Use of a color brain TV set, for recording biocurrents from thousands or millions of points on the brain, is foreseen. The development of such a device would be based on the principle of transforming biocurrent oscillations into a given variation in color. Amirov said that the application of TV technology in conjunction with radioactive isotopes, holds particular interest and promise for studies of the brain and other physiological functions.

## II. SPEECH RECOGNITION

29. Mal'tsev, A. F. [Candidate of Chemical Sciences, Associate Professor, State Committee on the Coordination of Science and Research in the USSR] A solid scientific basis is necessary. Vestnik vysshey shkoly, no. 11, 1963, 60-62.

Reference is made to a conference on programmed teaching held in Kiev in 1962. Leaders of schools of higher education were encouraged to support the program of development in this field. The proposals of the Scientific-Technical Council for programmed teaching for the period 1964-65 are described. The work is to be implemented at Moscow State University and at the Institutes of Psychology and General and Polytechnical Education of the Academy of Pedagogical Sciences RSFSR. Included in the program will be studies of the psycho-physiological laws of speech recognition. These studies will be conducted at the Moscow Pedagogical Institute of Foreign Languages, Tbilisi University, and the Language Institutes of the Ukrainian, Armenian, and Kazakh Academies of Sciences. Technical documentation will be developed by the Moscow Energy Institute and the Special Design Bureau of the Ministry of Higher and Secondary Specialized Education of the USSR. The Institute of General and Polytechnical Education RSFSR will also participate in the general plan. Several schools of higher education are currently working on programmed teaching. Included are: the Moscow Polygraphical and Machine-Instrument Institutes, Leningrad University, the Kiev and Kuybyshev Polytechnical Institutes, Sverdlovsk Pedagogical Institute, Leningrad Institute of Pure Mechanics and Optics, the Rostov Institutes of Agricultural Machinery and Railroad Transport Engineering, and the Novosibirsk Electrotechnical Institute.

30. Demidov, V. Compressed voice (speech). Znaniye-sila, no. 11, 1963, 52-54.

Machines capable of identifying up to 80—90% of the numbers spoken by any person were built in 1957 in the USA and in 1961 in Japan. A machine developed by the Soviet scientist G. G. Tsemd', however, is said to be capable of correctly identifying 99 percent of the numbers spoken to it. Voice-dialed telephones and voice-programed computers will be developed on the basis of such machines.

31. Kondratov, A. Semeiologists talking. Znaniye-sila, no. 3, 1963, 10-12.

The general idea of the science of semeiotics and its basic concepts are discussed. Semeiology, the science of signs or symbols, is characterized as a universal science which covers and interconnects all sciences. Having originated within mathematics in the form of mathematical logic, semeiology was expanded by linguists who needed a tool to be used to analyze languages, their relative differences, and the relation of language to other means of communication. Since all communication presupposes the existence of a society, the interest of anthropologists, sociologists, economists, etc., in semeiology is understandable. Physiologists and psychologists are trying to locate the language "center" in our organism. Psychiatrists and physicians deal with disturbances in the human communication system. The role of semeiology in the humanities is similar to that of mathematics in the natural sciences.

Semeiology is only at the beginning of its development; its terminology is still far from scientific exactitude. Nevertheless, it is developing in the direction of an exact science and with time will reach the level of mathematics. The applications of semeiology in education are being stressed since the process of learning can generally be reduced to the acquisition or mastery of some system of symbols, as in mathematics, chemistry, etc. The same may be said of learning languages. Reference is made to a recent symposium on semeiology organized by the Linguistics Section of the Council on Cybernetics of the Academy of Sciences USSR. At that symposium, the Linguistics Section and the Sector of Structural Typology of the Institute of Slavic Studies were assigned the task of organizing material for programmed learning of languages by means of cybernetic devices. Here, the close relation and interdependence of semeiology with cybernetics becomes apparent.

Some basic concepts of semeiology are explained as follows. A signal is defined as the material carrier (pulses of electric current, letters of the alphabet, pictures, etc.) of information. A special category of signals includes signs. The message carried by a sign or sequence of signs has a "sender" and a "receiver" or addressee. In written language, only combinations of characters known as words fall into the category of signs, since lesser components—letters, syllables, phonemes—have no meaning attached to them, and form only the elements which make up a sign. A system composed of signs has the

advantage of permitting a practically unlimited number of message-carrying words to be built from a score of primary characters, giving the system limitless flexibility and adaptability to communicate messages of any content and complexity.

Various kinds of sign systems, which have the advantage of being numerically understandable, will find application in different branches of science. In addition to systems of arbitrary symbols such as mathematics, many other systems will serve as message carriers. Illustrations, diagrams, charts, drawings, numbers, etc., have been used widely as carriers of understandable messages wholly detached from any particular language. Semeiologists are working toward a universal system of signs which would permit non-language communication between scientists and would in addition lend itself for use with cybernetic-information-storage and retrieval equipment.

32. Saparina, Ye. The problem of the creation of a speaking machine. Znaniye-sila, no. 10, 1962, 29-32.

The article discusses certain characteristics and peculiarities of oral speech which pose difficult problems for its use in machines. Reference is made to laboratories of experimental phonetics in Moscow, Leningrad, and Tbilisi, where investigations of these problems are being conducted. Variations in the pronunciation of vowels depending on their position in words and the role of the position of the stressed syllable in identifying the meaning of a word are among the features which are not expressed in terms of frequency, spectrum, or amplitudes of sound oscillation, and therefore cannot be identified by a machine, which operates on the basis of these characteristics only.

The faculty of speech is analyzed from the standpoint of certain defects in its use and understanding. The spoken word is defined as a signal of signals, and speech as a secondary signal system, in which the impressions received from the outside world are coded in terms of language and in that form are stored in the brain. This secondary signal system is a unique feature of the human brain as distinguished from that of animals, who perceive the images of the outside world directly, as they come. The human brain has no definite "speech center" among its specialized parts. The functions connected with speech are divided among various parts of the brain, as illustrated by a description of some experiments on patients with speech defects carried out by aphasiologist E. S. Beyn of the Institute of Neurology. Speech production, for instance, is governed by the rear section of the front convolution of the brain. The process of writing, i.e.,

planning the movements of the hand to produce a character, develops in field 40. Field 22 is responsible for internal feedback of the pronounced sound, as if to check its correctness before the next sound is produced, etc. The perception of speech sounds, the identification of sounds as signals for certain objects, the "recognition" of sounds or characters as a part of the recognition process in general, are other individual functions necessary for communications by speech, so far as its elements, i.e., words and corresponding concepts, are concerned. But before being understood, a sequence of words must be carried out. The whole mechanism of communication by speech appears to be beyond the capabilities of any cybernetic device, and many of its intricacies are not yet understood by scientists. The fact that this higher psychic activity is based on the transmission of signals, even "secondary signals," means that it can be studied by methods of the information theory.

The efficiency of the human "system of communication" is characterized by a description of certain experiments carried out in the Department of Psychology of Moscow University under Professor A. N. Leont'yev. The experiments were aimed at the establishment of time intervals needed for the comprehension of signals and reaction to them under various conditions. A study was made of the effect of the amount of information carried by a signal and the time needed for a proper reaction. Reference is made to experiments by the British psychologist Hick [Hik], whose results indicated that the speed of signal processing by the human organism was about 5 bits per second. These results, however, were applied to a sequence of similar signals given at equal intervals. The experiments at Moscow University dealt with sequences of signals which varied in character (urgency, expectedness, etc.), in intervals etc. to establish the psychological effects of these circumstances. By assigning various degrees of importance to certain signals, it was established that the human system is capable of much faster reactions to signals of higher importance. This is a distinctive feature of the human organism which is lacking in technological systems. Also, the human system, consciously or subconsciously, adapts itself to the "signal structure probability," i.e., to the regularity pattern in a sequence. This also helps to shorten further the reaction time to rare signals. Although this occurs at the expense of more frequent signals, such adjustment means an overall gain in efficiency. Under these circumstances it was found that up to 25 bits, instead of five, could be consciously processed in a second.

The problem of carrying capacity, however, remains unsolved, since different channels operate at different speeds



(the olfactory system, for instance, being the slowest). Everything perceived by the human brain is retained, according to Dr. H. Frank, for 10 seconds in the so-called "short memory" storage (to distinguish it from the "long-memory" storage, or "archive"). His experiments showed that the limit to perception is about 16 bits per second, so that the number of bits "in process" at any moment will amount to 160, of which only 0.7 bits, or 1/25th of all perceived, is conveyed to the "archive" for long-term storage. About one-half of the number of bits carry the immediate excitation, while the other half is needed for "understanding" a sequence of excitations, e.g., for making a word out of a number of letters. Some researchers hold that only about half of the 16 bits are actually perceived, while the rest are used for the retrieval of corresponding information from the memory.

In conclusion, the author maintains that cybernetics is helpful in the investigation of human psychology and the secondary signal system as manifested in the phenomenon of speech. At the same time, the facts regarding speech make the solution of the problem of a speaking machine difficult. The author states that a model of the psychic activity of the human organism is needed.

33. Ramishvili, G. S. An experiment on the automatic identification of speakers. IN: Akademiya nauk GruzSSR. Soobshcheniya, v. 36, no. 2, 1964, 279-286.

The author describes a method for selecting key words which best display the individual characteristics of a speaker and presents general requirements for such words. Final selection is made on the basis of actual recording and analysis. The speech signal at the output of the analyzer is determined according to frequency, time, and amplitude. For the computer input, the signals are quantized in time and amplitude. Further processing is based essentially on these two quantities. The computer output is expressed in sets of discrete numbers, which can be assumed to fill a space in a certain order. Identification of speakers is possible if many repetitions of a word by a speaker result in a close aggregate of numbers which stands apart from another aggregate belonging to another speaker of the same word. The larger the number of speakers, however, the more overlaps there will be between the aggregates. Thus, additional information is needed for identification. The experiments showed that ten words chosen by the method described were good carriers of individual speech characteristics. Such key words as "vy" (you), "da" (yes), and "ya" (I) served best. An experiment is described in which the word "vy" is pronounced by 20 different speakers. Of the 250 utterances of the word, 200 were used to establish standards for all 20

speakers. Tests were actually made on 210 utterances. These utterances were compared with all 20 standards and assigned to the speakers with whose standard they agreed best. The percentage of correct identifications was 92.4. Results can be improved by using a larger number of key words, each of which would furnish a new characteristic for identification. The author refers to works by Bell Laboratories, S. Pruzansky (JASA, v. 35 no. 3, 1963), and G. Sebestyen (IDE Trans, Inform, Theory, 8, no. 5, 1962, 82-91) and presents a sample videogram of the one-syllable Russian word "vy" (you) pronounced three times by three different speakers to illustrate the individual characteristic of each speaker's speech signal.

### III. PSYCHOCHEMICALS

1. Zakusov, V. V. [Director, Institute of Pharmacology and Chemotherapy of the Academy of Medical Sciences, USSR, Member, Academy of Medical Sciences USSR] and S. V. Anichkov [Head, Department of Pharmacology of the Institute of Experimental Medicine, Academy of Medical Sciences USSR, Member, Academy of Medical Sciences USSR] Psychopharmacology. Nauka i zhizn', no. 4, 1962, 80-84.

The authors explain, in popular terms, the pharmacology of substances affecting the "higher nervous activity," the materialist's expression for "psychic phenomena." The effect of such preparations as adrenalin, caffeine, and valerian, along with a number of modern preparations, is described and the organs affected by them identified. The authors hope to promote better understanding of the significance of the problem and to stimulate a more vigorous development of the field.

#### IV. HYPNOPEDIA

1. Pushkina, I., and V. Zucharis. Learning during sleep. Problems solved when asleep. Foreign language can be learned 3—4 times faster. Will the new method be accepted? *Mokslas ir technika*, no. 8, 1964, 26-27.

The authors review American, German, French, and Russian experiments on sleep-teaching. Several examples of hypnopedic problem-solving in mathematics, chemistry, and zoology are mentioned. Professor L. Vasilyev's explanation of this phenomenon is given. Experiments performed in Moscow in 1961 are described. These experiments were for the purpose of determining whether a foreign language can be taught effectively to a student who is in a natural sleep and whether it is easier to learn simple or difficult words. Pupils of the experimental group learned the material (foreign language words) 2 to 3 times better than the control group. Separate words were retained more easily than textual passages. Greater retention of the material was exhibited by those who had previously indicated a desire to learn. The period of light sleep which comes 20—30 min after falling asleep was determined to be the most effective period for teaching. Also described are the experiments in teaching during natural sleep supervised by Candidate of Philological Sciences L. Bliznitsenka. Bliznitsenka used a device called the "hypnoinformator" in experiments involving the teaching of a foreign language and a telegraphic code. Her results showed that a subject can learn from 92—100% of the material presented to him during sleep. Bliznitsenka thinks that the period required for teaching a foreign language can be reduced by 3 to 4 times. The possibility of deleterious effects from sleep-teaching will be the subject of future investigations.

2. Pervov, L. G. [Candidate of Medical Sciences, Institute of Physiology of the Academy of Sciences USSR] Hypnopedic. *Priroda*, no. 6, 1962, 48-49.

This article is in response to a reader's question as to whether hypnopedic is possible in practice and what effects it has on man's health. The author is of the opinion that in a relatively small number of cases positive results can be achieved. The subject, he feels, requires more study.

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